Acid Resistance of Glass Fibre Composites with Different Layup Sequencing Part II: Degradation Studies

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ABSTRACT: The degradative effects of sulphuric acid on glass fibre composites with different layup sequencing were studied by monitoring the changes in the Inter Laminar Shear Strength (ILSS) using short beam shear specimens. The composite specimens used for the diffusion studies in Part I were chosen for the degradation studies. The results of the studies indicated that isopthalic polyester resin composites retained maximum percentage of Inter Laminar Shear Strength, while those of the General Purpose Resin showed higher degradation. The degradation increased as the concentration of the sulphuric acid was increased, indicating that degradation was a dominant phenomenon at higher concentrations. The weave compactness of woven roving type glass reinforcement which formed the face skin in the case of composites of sequential layup C accounted for better performance of these composites in Sulphuric acid environment, while the presence of a loosely bonded chopped strand mat as the skin in composites of sequential layup A caused higher degradation.

INTRODUCTION

THE PERFORMANCE OF laminated composites under service conditions depends largely upon its interlaminar shear strength (ILSS-a resin dominated property). ILSS is often used as a key criterion in assessing the soundness of the fibre matrix interface. Hence, this property was chosen for composite degradation studies.

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Under the influence of environmental conditions interfaces between the fibres and the matrix, and the thin layers of pure matrix between fibres are susceptible to degradation. Since the matrix has lesser mechanical strength when compared to the reinforcement, it transfers any applied load to the fibre matrix interface in the form of shear. Hence, the fibre matrix interface is of paramount importance if the composite is to withstand the externally applied loads effectively. Interlaminar shear stress failure occurs when composite plates are loaded in bending with short span to depth ratios as defined in a three point short beam bending test (ASTM-D-2344-72). O. M. K. Joshi [1] studied the effect of moisture on shear properties of carbon fibres. N. J. Pagano and R. B. Pipes [2] studied the ILSS of different composite materials. The assessment of ILSS in the case of composites prior to and after exposure to the acid environment gives an insight into the degradation of the fibre matrix interface. Shankar Singh et al. [3] studied the degradation of Short Beam shear (SBS) and impact strength (Izod) properties of glass epoxy composite specimens with sequential arrangement of woven roving and chopped strand mat reinforcements immersed in water at 298 *k* and 323 *k*. Composites above certain fibre content showed high initial shear strength and degraded faster than low fibre content composites signifying the crucial role played by the matrix.

EXPERIMENTAL

The laminates prepared using different resin systems and fabric layup sequences [part 1] were used for determination of interlaminar shear stress.

A span to depth ratio of 5:1 was maintained throughout. The test specimen dimensions were 20 mm × 10 mm × 2 mm. The specimens were coated along thickness to prevent edge diffusion effects. These were then immersed in distilled water and in sulphuric acid of 15%, 25%, and 35% concentrations. These specimens were removed at regular time intervals and tested on an INSTRON 6025 Universal Testing Machine (UTM). The load vs deflection curve for unexposed and exposed specimens were plotted. The maximum load which the composite could hold was used to determine the interlaminar shear stress based on the equation.

$$\text{ILSS} = 3P/4bh$$

where,

P is the load applied, (Kg)

b is the width (mm)

h is the specimen thickness (mm)

Plots of % ILSS retained vs period of exposure were generated for all the cases.

RESULTS AND DISCUSSIONS

Behaviour of Composite Specimens of Different Resin Systems and Sequential Layup A in 35% Acid

After five months of exposure, the composite laminates made of Bisphenol and isophthalic polyester resins exhibited higher percentage ILSS retention compared to those of the rest of the resin systems. The ILSS degradation of the composite specimens made of general purpose polyester resin was the highest. This indicates that isophthalic and Bisphenol grade polyester resins offer the best resistance to sulphuric acid environments while general purpose polyester resin is prone to sulphuric acid attack, with the epoxy grades falling in between.

Figure 1 gives the plot of % ILSS retained vs the exposure time in months for composite specimens of layup sequence A in 35% H_2SO_4 for different resin systems.

Effect of Acid Concentration

In the case of composite specimens immersed in distilled water, there is a steep decrease in the ILSS values while this decrease tapers off as the exposure period increases. This indicates that the composite specimen is reaching saturation. In the case of composite specimens immersed in 15% sulphuric acid, the % ILSS

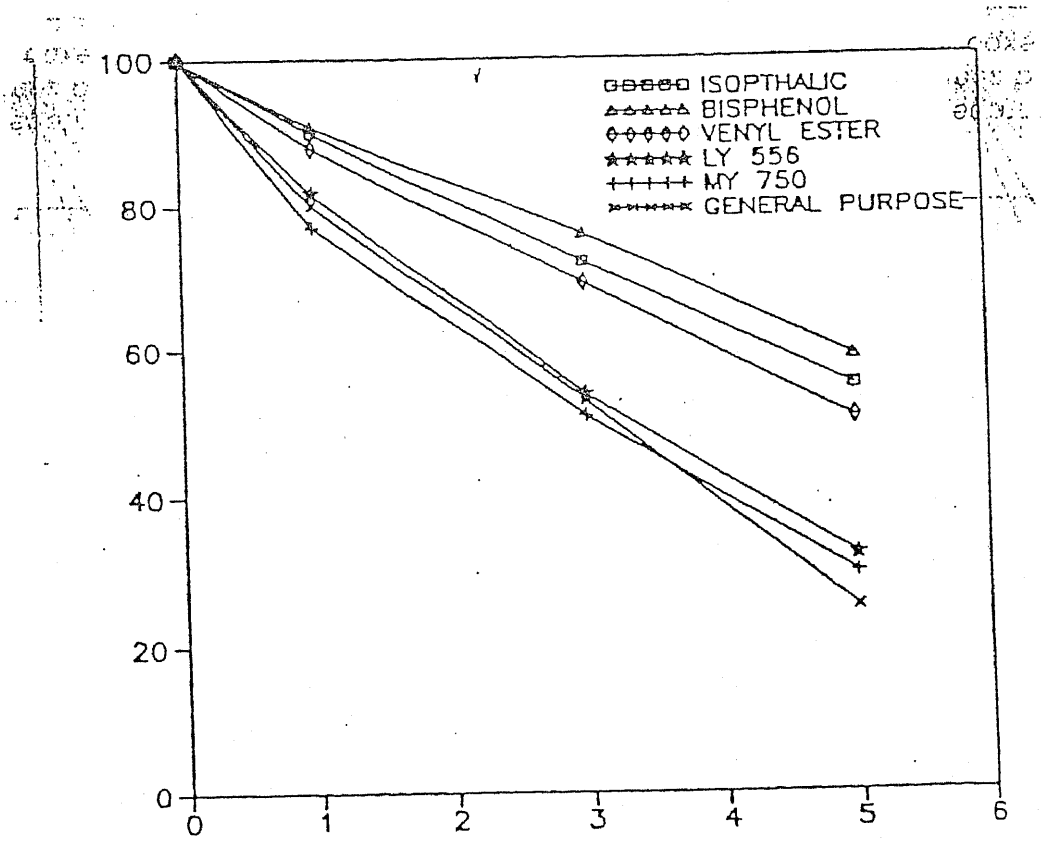

Figure 1. Comparison of percentage ILSS retained of composite specimens fabricated using different resin systems and sequential layup A, in 35% sulphuric acid. Title: X-axis—period of exposure in months, Y-axis—percentage ILSS retained.

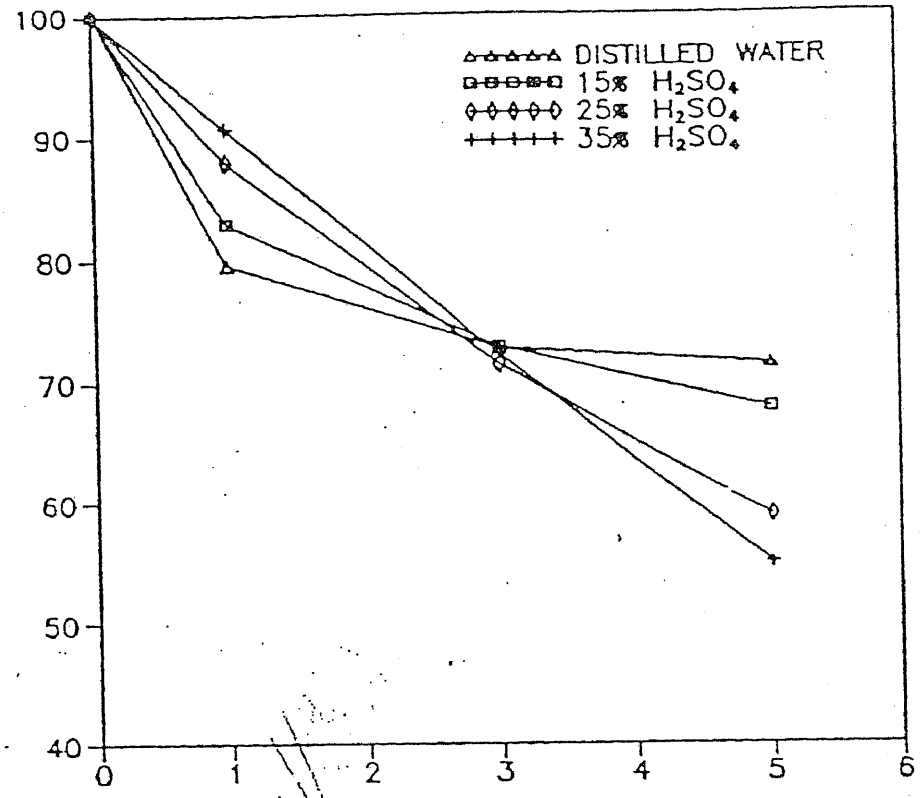

Figure 2. Comparison of percentage ILSS retained of composite specimens fabricated using isopthalic polyester resin and sequential layup A, as a function of sulphric acid concentration. Title: X-axis—period of exposure in months, Y-axis—percentage ILSS retained.

retained follows almost a similar trend as in the previous case. But, the % ILSS retained is much less when compared to the previous case. This indicates that degradation has just begun to set in. In the case of composite specimens immersed in 25% and 35% sulphuric acid, the percentage ILSS retained falls off rapidly in the increasing order (Figure 2). This indicates that degradation is predominant over the diffusion phenomenon.

Effect of Fabric Layup Sequence

Composite specimens fabricated using the layup sequence A, B, C respectively, were immersed in distilled water, 15%, 25% and 35% sulphuric acid solutions. It is clear that the composite specimens fabricated with sequential layup C have the highest ILSS and the composite specimen fabricated with sequential layup A have the least ILSS. This shows that the fibre matrix interface bond is strongest in the case of former while it is the weakest in the case of composite specimens fabricated using sequential layup A. Figures 3–6 show the plots of % ILSS retained vs exposure period in months for composite specimens immersed in distilled water, 15%, 25% and 35% sulphuric acid.

In every case, the composite specimens of layup sequence C retain the highest percentage ILSS as compared to specimens of layup sequence A. This is attributable to the weave compactness of the woven roving mat which forms the top and bottom layers in the case of the former type of composites.

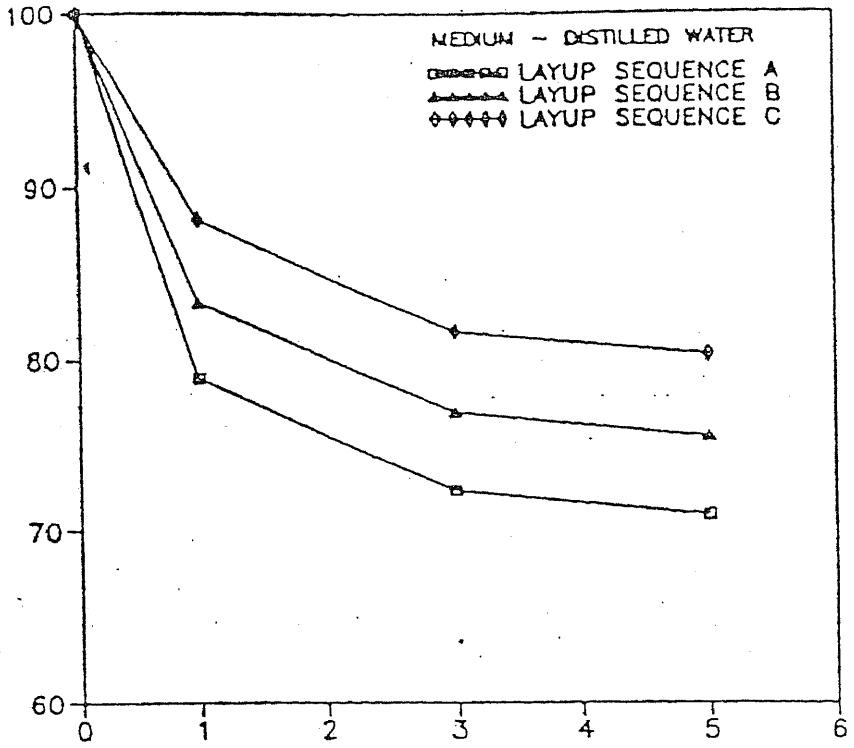

Figure 3. Comparison of percentage ILSS retained of composite specimens fabricated using isopthalic polyester resin and various sequential layups in distilled water. Title: X-axis—period of exposure in months, Y-axis—percentage ILSS retained.

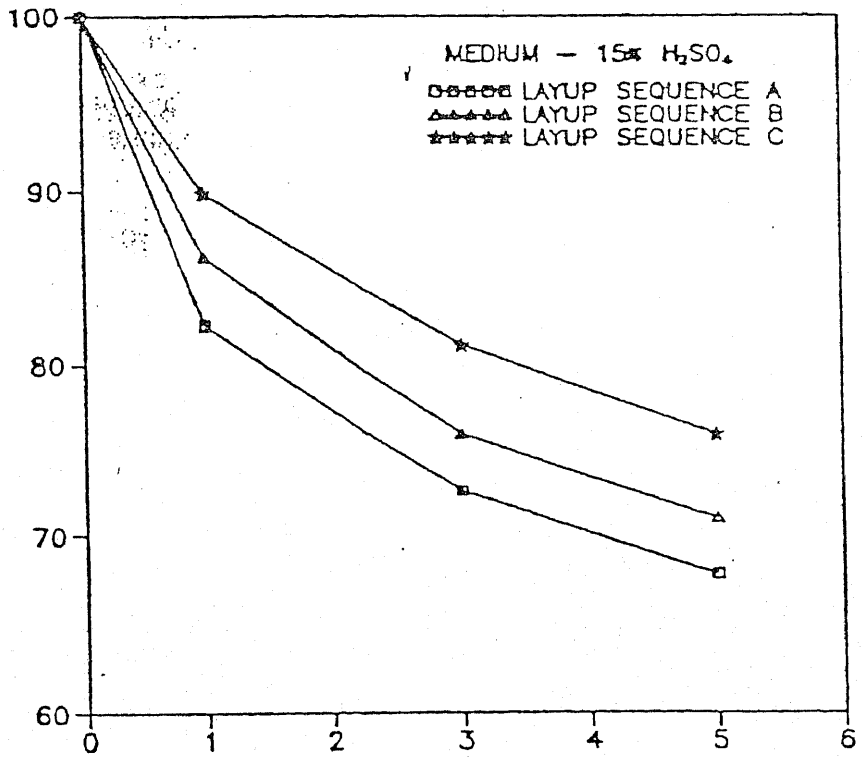

Figure 4. Comparison of percentage ILSS retained of composite specimens fabricated using isopthalic polyester resin and various sequential layups in 15% sulphuric acid. Title: X-axis—period of exposure in months, Y-axis—percentage ILSS retained.

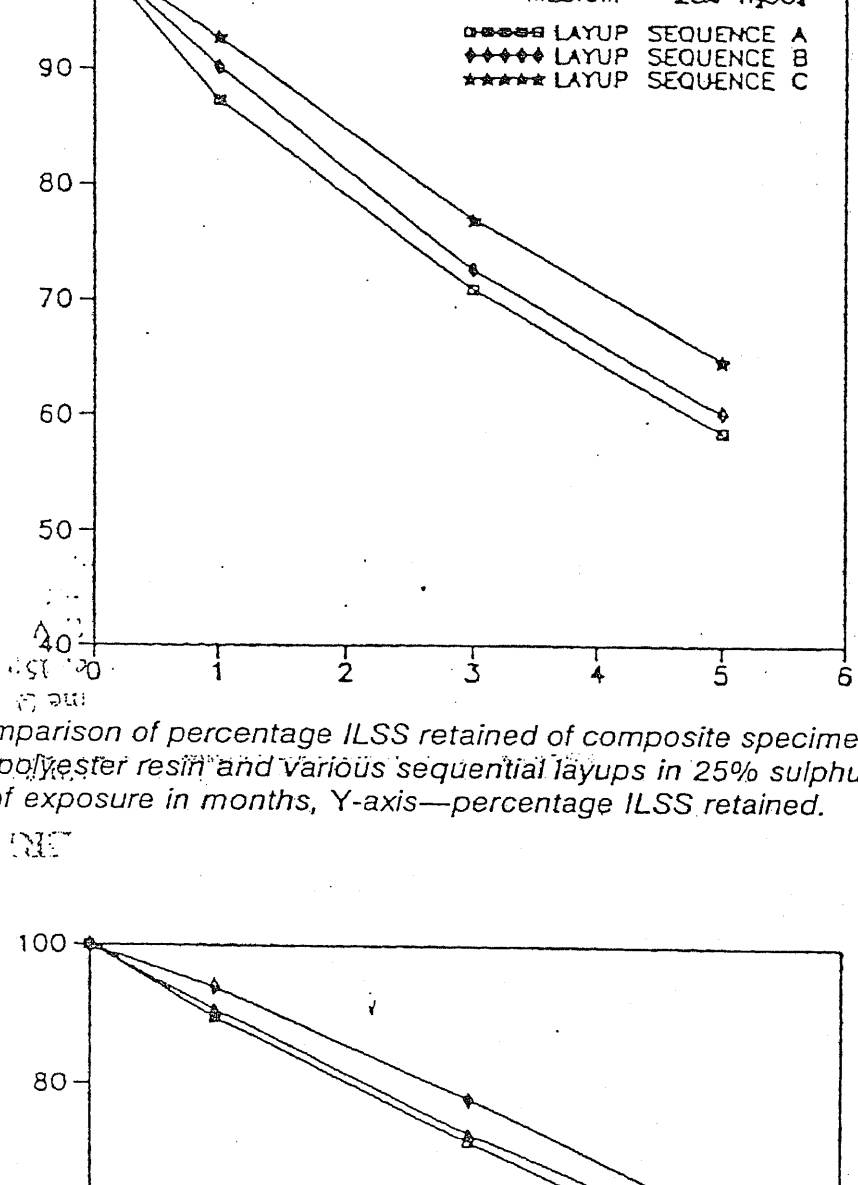

Figure 5. Comparison of percentage ILSS retained of composite specimens fabricated using isopthalic polyester resin and various sequential layups in 25% sulphuric acid. Title: X-axis—period of exposure in months, Y-axis—percentage ILSS retained.

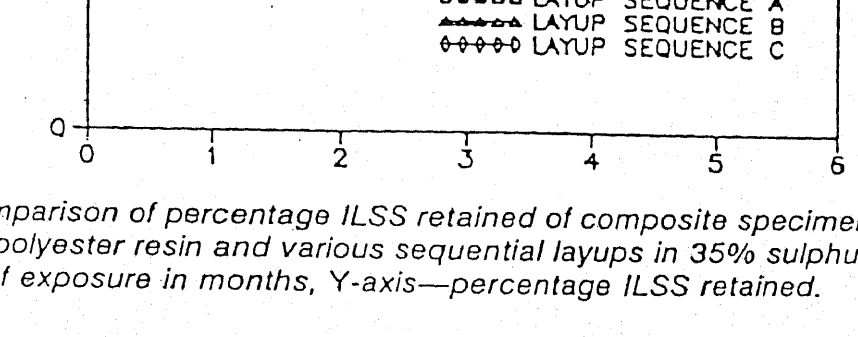

Figure 6. Comparison of percentage ILSS retained of composite specimens fabricated using isopthalic polyester resin and various sequential layups in 35% sulphuric acid. Title: X-axis—period of exposure in months, Y-axis—percentage ILSS retained.

An interesting observation can be made from these figures that while the degradation trends continue to be the same among different types of specimens, the difference in their degradation levels vanish. This degradation indicates that at high acid concentration, the degradation phenomenon dominates diffusion.

CONCLUSIONS

1. Composites of Isopthalic and Bisphenol grade polyester resins retain the highest percentage ILSS in any given acid environment.
2. The fall in the percentage ILSS retained increases with increases in the acid concentration.
3. In the case of distilled water immersion, the percentage ILSS retained falls off steeply initially, but as the period of exposure increases, further drop is negligible.
4. Among the various layup sequences considered, the composites of layup sequences C retained the highest percentage ILSS. For all the acid concentrations considered.

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